Neural coding of binaural cues between acoustic and electrical stimulation in an animal model of single-sided deafness

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Cochlear implant (CI) users increasingly have significant acoustic hearing in the non-implanted ear and continue to use a hearing aid (HA) in the non-implanted ear. In addition, CIs are becoming a treatment option for people with single-sided deafness (SSD). These populations of CI users can potentially enjoy the benefits of binaural hearing such as improved sound localization and speech reception in noise by utilizing binaural cues present between the two different modes of stimulation. Here, we investigated the sensitivity of midbrain auditory neurons to interaural time differences (ITD) with bimodal stimulation to understand how the binaural cues are represented in the central auditory pathway and identify the most effective stimulation parameters for delivering these cues.

Single-unit recordings were made from the inferior colliculus (IC) of an unanesthetized Dutch-belted rabbit that was deafened and implanted in one ear and had normal hearing in the non-implanted ear. Periodic trains of acoustic clicks and electric pulses at low repetition rate (20-80 Hz) were used to characterize bimodal ITD sensitivity of the IC neurons. In many neurons, the temporal discharge pattern showed strong responses to both stimuli for large ITDs, either acoustic leading or electric leading. The acoustic response latency was longer than the electric latency reflecting the additional biological delay of the sound traveling through the external, middle and inner ear. For smaller delays near zero-ITD after adjusting for the difference in response latencies, IC neurons showed clear binaural interaction to the bimodal stimuli in that the firing rate could be either increased or decreased relative to the rate for stimulation in either mode. We observed similar shapes of ITD tuning curves such as peak and trough types as previously observed in response to pairs of acoustic clicks or electrical pulses. Neural ITD discrimination thresholds were in the similar range as thresholds observed in IC neurons of bilaterally deafened and implanted animals.

The results show that neurons in the auditory midbrain can be sensitive to binaural cues in combined acoustic and electric stimulation and suggests binaural benefits with bimodal hearing could be improved by providing better access to binaural cues in SSD/CI users and HA-CI users.

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